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Project No. E-25-Q01 (R5974-0A0) GTRC/~~GIT~~ DATE 7/11/85

Project Director: W. Z. Black School/~~Lab~~ ME

Sponsor: Pacific Gas & Electric Co.

Type Agreement: Standard Research Agreement dated 6/28/85, Sponsor #Z19-5-169-85

Award Period: From 6/28/85 To ~~6/27/86~~ ~~12-31-86~~ 9-30-87 (Performance) N/A (Reports)

Sponsor Amount: This Change / Total to Date

Estimated: $ ______ $ 30,645

Funded: $ ______ $ 30,645

Cost Sharing Amount: $ N/A Cost Sharing No: N/A

Title: Conductor Thermal Studies

ADMINISTRATIVE DATA

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Defense Priority Rating: N/A

Military Security Classification: N/A

(or) Company/Industrial Proprietary: See Below

RESTRICTIONS

See Attached N/A Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval – Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with Sponsor

COMMENTS:

A non-disclosure Agreement has been executed for this project.

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NOTICE OF PROJECT CLOSEOUT

Date 5/24/89

Project No. E-25-Q01 Center No. R5974-0A0

Project Director W. Z. Black School/Lab ME

Sponsor Pacific Gas & Electric Co.

Contract/Grant No. Agreement dtd. 6/28/85 GTRC XX GIT ____

Prime Contract No. ____

Title Conductor Thermal Studies

Effective Completion Date 9/30/87 (Performance) 10/30/87 (Reports)

Closeout Actions Required:

- X None
- ___ Final Invoice or Copy of Last Invoice
- ___ Final Report of Inventions and/or Subcontracts
- ___ Government Property Inventory & Related Certificate
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- ___ Release and Assignment
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Research Proposal

CONDUCTOR THERMAL STUDIES

Submitted to

Pacific Gas and Electric
Department of Engineering Research
San Ramon, California

Continuation of
Georgia Tech Contract E25-Q01
PG&E Contract Z19-5-169-85

Submitted by

Wm. Z. Black, Professor
George W. Woodruff School of Mechanical Engineering
Georgia Institute of Technology
Atlanta, Georgia

April 1986

RESEARCH OBJECTIVES

The George W. Woodruff School of Mechanical Engineering at the Georgia Institute of Technology proposes a research project which is an extension of work started in June 1985 and funded by PG&E's Department of Engineering Research through June 1986. The result of this work has been a user-friendly IBM-PC version of a program called PGEAMP which is capable of calculating transient ampacity values for bare overhead conductors.

During the first year of this project, measurements made at DER's wind tunnel showed that PGEAMP was capable of predicting both steady-state and transient conductor temperatures within 4% of measured temperatures for several different conductor sizes. The maximum error produced by PGEAMP was $3^{o}C$ for both steady-state and transient conditions. PGEAMP was also compared with the commonly used House and Tuttle model and it consistently predicted temperatures within $3^{o}C$ of this model.

The transient ampacity program has also been modified so that it more closely fits PG&E's needs as a transmission line design tool. PGEAMP has been modified so that it will accomodate several different choices of input units and it will also provide simplified or expanded output information. These revisions have made PGEAMP easier to use while providing information that is valuable when designing a transmission or distribution system.

The proposed work is an extension of the work performed during the first year of the contract. The objectives of the work are as follows:

1. PGEAMP will be modified so that it has real-time capabilities. That is, the program will be capable of communicating on a real-time basis with a weather station and calculating the temperature of the overhead conductor. This objective will probably require a separate interface program that will receive input data through a modem and modify the data

so that it is compatible with the input format expected by PGEAMP. The interface program will most likely be written in an assembly language code.

The average weather data from each weather station will be expected to arrive at the computer input port in a digitized form at an interval no less than 5 minutes apart. Communication will be achieved through a modem that operates at a 300 Baud rate using only ASCII numbers. The user is expected to provide a single value of a time interval and all weather data will be received by the program uniformly separated by this value of time interval. If multiple weather stations are utilized, each weather station will send data to the computer at a fixed interval in a specific sequence.

2. PGEAMP will be modified such that it will be able to monitor a maximum of five weather stations each reporting a different set of weather conditions (air temperature, wind velocity, wind direction and line current) and a maximum of five different conductor sizes. The user will provide input information so that the program can select among the weather stations and line sizes and provide temperature calculations for only the lines of interest.
3. The program will be modified so that the predicted line temperatures can be routed to either a printer or to a diskette or to both devices.

Deliverables

A final report will be submitted to DER no later than one month after the end of the project. The report will summarize the results of the project and it will include a users manual for PGEAMP. In addition, several copies of PGEAMP will be provided on diskettes.

Personnel

The Principal Investigator for this project will be W. Z. Black, Professor of Mechanical Engineering at Georgia Institute of Technology. His resume' is attached to this proposal. He will devote 20% of his time during the duration of the project. He will travel to San Ramon once during the project to coordinate efforts and to report on progress achieved. The trip will be arranged on a mutually agreed date.

The programming necessary to convert PGEAMP will be carried out by a Master's degree student in the School of Mechanical Engineering. This student will work at DER in San Ramon between June 18 and September 18, 1986. Funding will be provided for his work to be performed in San Ramon and for continuation of his work at Georgia Tech during the Fall Quarter 1986. Funds will also be included in the budget for roundtrip travel for the graduate student to San Ramon.

The graduate student who will work on this project will be knowledgeable in the area of heat transfer and computer applications. The student will also be familar with the details of PGEAMP and the problems of thermally modeling of overhead conductors.

Effective Dates

The project will begin on June 10, 1986 and will terminate on December 31, 1986.

BUDGET

Salaries	
Principal Investigator 20% effort during Summer and Fall Quarters 1986	$7,600
Master's Student Full time at San Ramon June 18 to September 18, 1986	$6,500
1/3 time GRA Fall Quarter 1986 including tuition	$2,200
Fringe Benefits	
21% of Principal Investigator's salary	$1,596
Travel Expenses	
One roundtrip to San Ramon for Principal Investigator	$ 800
One roundtrip to San Ramon for Graduate Student	$1,200
Computer Expenses, Supplies and Miscellaneous Expenses	$1,000
Subtotal	**$20,896**
Overhead	
63.5% of subtotal	$13,269
TOTAL	**$34,165**

Rate is effective for the period 7/1/85 - 6/30/86 and is subject to change thereafter.

CONDUCTOR THERMAL STUDIES
(PGEAMP VERSION 3.01)

George W. Woodruff School of Mechanical Engineering
Georgia Institute of Technology

July 1987

Final Report
Research Project E25-Q01

CONDUCTOR THERMAL STUDIES
(PGEAMP Version 3.01)

Submitted to

Lloyd Cibulka
William Steeley

Pacific Gas and Electric
Department of Engineering Research
San Ramon, California

submitted by

W. Z. Black, Professor
J. C. Savoullis, Graduate Research Assistant

George W. Woodruff School of Mechanical Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332

July 1987

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SECTION 1

INTRODUCTION

This report describes a computer program called PGEAMP, for Pacific Gas and Electric Real-Time Ampacity program, which can calculate the dynamic temperatures of overhead conductors. The program was developed as part of a two and one-half year research project in which the program results were verified in a series of wind tunnel tests. Also during that time, the program was modified so that it could accept weather and current data and calculate conductor temperatures on a real-time basis. Furthermore, the predictive option of the program was extended so that it is capable of calculating a conductor current necessary to provide an emergency conductor temperature after a given time interval that the conductor is subjected to a step change in current. This predictive program option compliments an existing predictive option where the time to reach an emergency limiting temperature is calculated.

In its present form, PGEAMP will calculate the thermal state of a conductor for three basic types of conditions: steady-state, transient or real-time and predictive behavior. The steady-state option is identical to the model that is commonly attributed to House and Tuttle. The real-time model permits transient temperature calculations for any variation in current or weather conditions. The predictive options permit the calculation of conductor temperatures and ampacity values when the conductor is subjected to step changes in current. The predictive option is intended to help operators judge the future behavior of the conductor when it experiences a change in current similar that which may occur during an emergency outage.

PGEAMP can calculate conductor temperatures for up to 25 different lines. The program can communicate with a maximum of five weather stations which report on real-time weather conditions including air temperature, wind speed and wind direction as well as the conductor current. Each weather station can report the weather and current for up to five different conductors at that one location. Therefore, the program is capable of calculating temperatures of 25 different size lines, all with different currents, and with different sets of weather conditions.

The program has the capability of predicting temperatures for eight different conductor types that are listed in Table 1.

Type	Conductor Material	Core Material
ACSR	1350-H19 Aluminum	Steel
AAC	1350-H19 Aluminum	1350-H19 Aluminum
AAAC	6201-T81 Aluminum	6201-T81 Aluminum
ACAR	1350-H19 Aluminum	6201-T81 Aluminum
All Copper	Hard Drawn Copper	Hard Drawn Copper
Alumoweld	1350-H19 Aluminum	Alumoweld
AAAC	5005-H19 Aluminum	5005-H19 Aluminum
SSAC	1350-H19 Aluminum 63% cond.	Steel

Table 1. Eight Different Conductors that can be Considered by PGEAMP.

Input to PGEAMP consists of 17 variables when either steady-state or real-time calculations are required; 19 variables are required when either predictive program options are selected. Detailed discussion of these variables appears in Section 5.

SECTION 2

EXPERIMENTAL VERIFICATION OF PROGRAM

The wind tunnel test facility at DER was used to conduct a series of experimental tests to verify the temperature predictions of PGEAMP. A test conductor was mounted in the wind tunnel in a tension device. Fans were used to circulate air past the conductor at various velocities and at various angles. The conductor had numerous thermocouples attached throughout the conductor cross-section and the air velocity, direction and temperature were carefully monitored. All test data were continually recorded on diskette by a Hewlett Packard data acquisition system connected to an IBM-PC.

Three different types of comparative tests were conducted: steady-state, real-time ampacity calculations and predictive calculations in response to step changes in current. Both AAC and ACSR conductors were used. The ACSR conductor was a Cardinal conductor (54/7, 954 kcmil, 1.196 inch outside diameter) and the AAC conductor was a Marigold conductor (61 strand, 1113 kcmil, 1.216 inch outside diameter).

The maximum percent difference between PGEAMP's temperature predictions and the measured average of the thermocouple readings was 2.25% or no more than $3^{o}C$ for both the transient and predictive tests. The program was within 4% or a maximum of $3^{o}C$ of the measured temperatures when the tests simulated steady-state conditions. PGEAMP was also compared with an existing steady-state program based on the House and Tuttle model and it was consistently within $3^{o}C$ of this model.

Several representative wind tunnel curves showing a comparison between PGEAMP and the measured temperatures are included below to give an impression of the program accuracy. More details of the tests and the program accuracy are included in a report submitted by J. C. Savoullis entitled "Final Report - Evaluation of EPRI (DYNAMP) Software for Transmission Line Conductor Temperature Rating", submitted to J. F. Hall and T. Hillesland, October 1985.

A comparative test using the AAC Marigold conductor is shown in Fig. 1. The conductor was subjected to a constant wind speed of 4.5 mph, perpendicular flow of air with a temperature of 30.4°C. The current was changed in a step fashion from 600 amps to 1500 amps and back to 600 amps in increments of 300 amps on 15 minutes intervals. Thermocouples recorded the transient response of the center and surface temperatures as shown in Fig. 1. The figure also shows the temperatures predicted by PGEAMP. At all times the differences between measured and calculated temperatures were within 2°C and the program predicted a temperature nearly mid-way between the measured surface and center temperatures.

Another comparison between PGEAMP and the measured conductor temperature for the Marigold conductor is shown in Fig. 2. This figure shows the temperature changes experienced when the conductor was subjected to three different step changes in current: 300-1200 amps, 300-1500 amps and 300-1800 amps. As in the previous comparison, the measured and predicted temperatures varied by no more than 2°C.

A final comparison of measured and calculated temperatures is shown in Fig. 3 for an ACSR Cardinal conductor. In this test the air flow

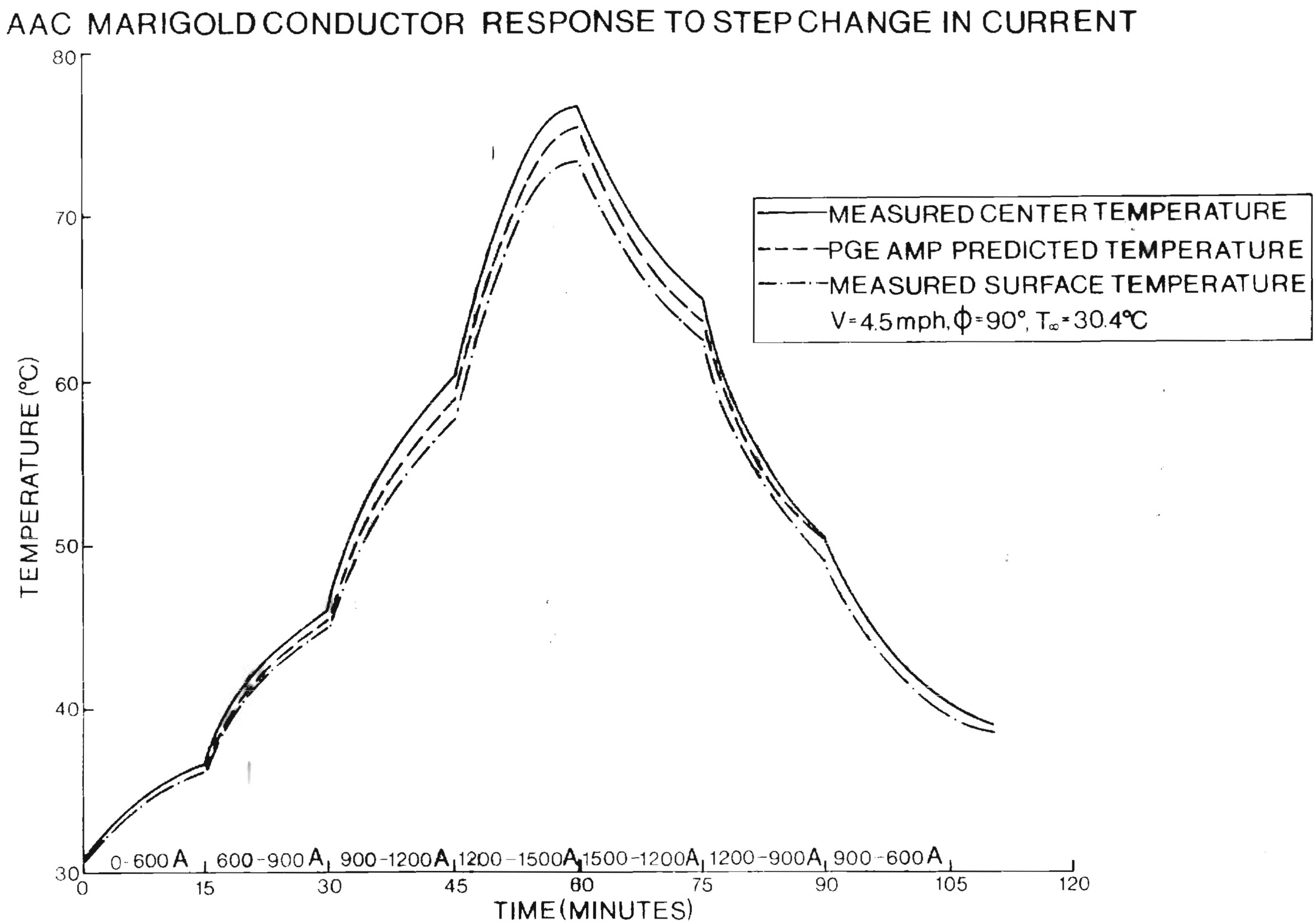

Figure 1. Measured and Predicted Temperatures for a Marigold Conductor Subjected to Step Changes in Current.

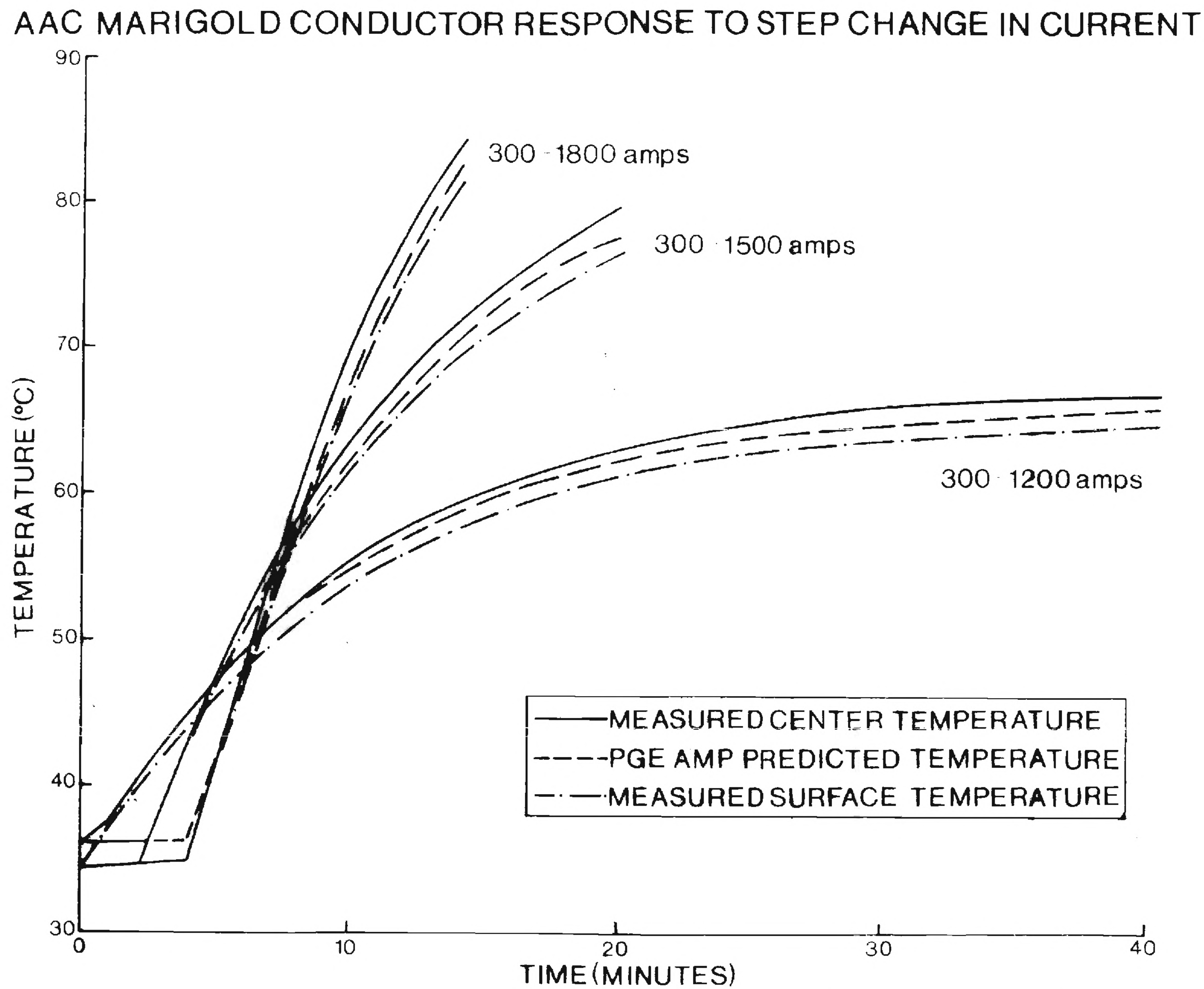

Figure 2. Measured and Predicted Temperatures for a Marigold Conductor Subjected to Step Changes in Current.

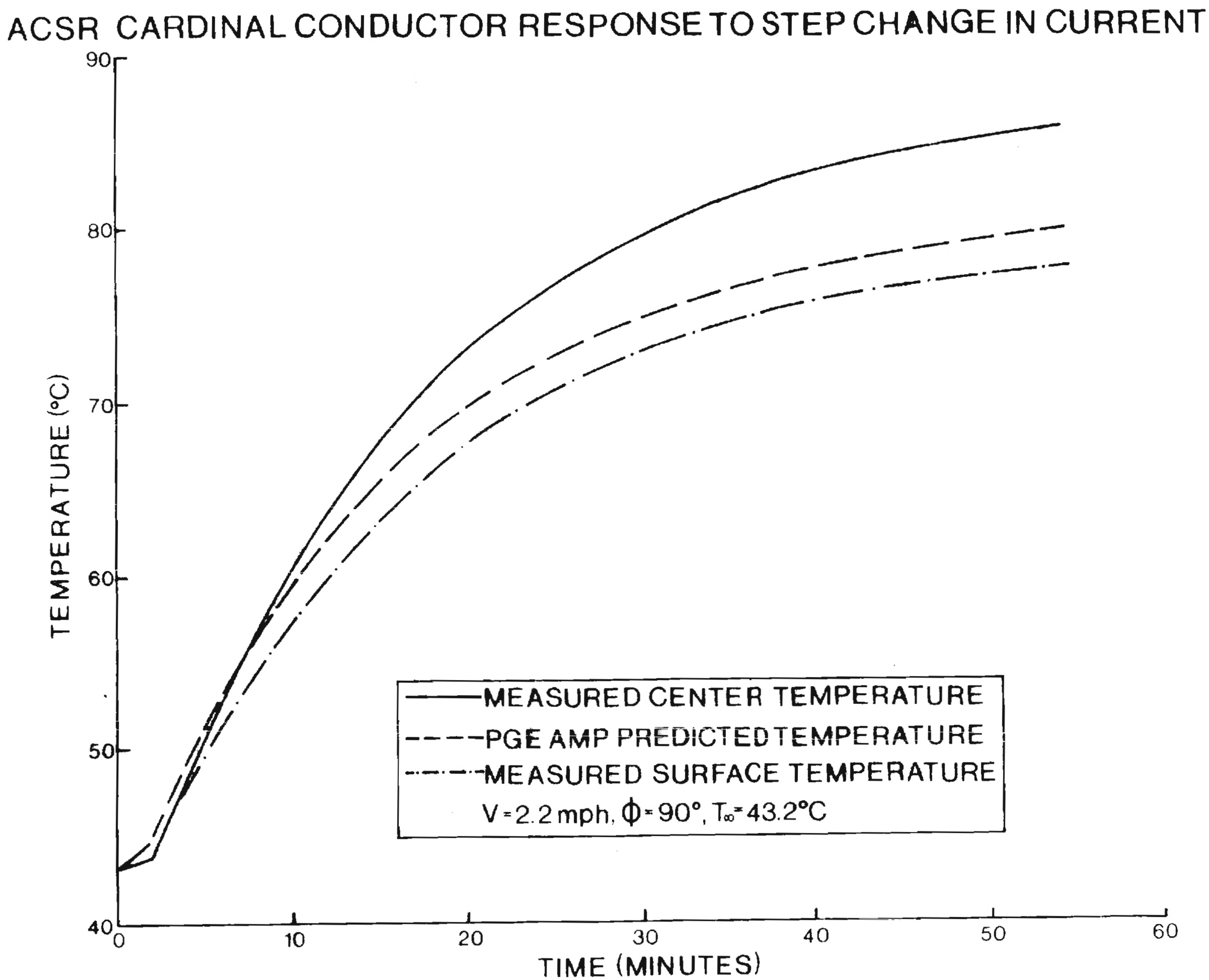

Figure 3. Measured and Predicted Temperatures for a Cardinal Conductor Subjected to Step Changes in Current.

perpendicular to the conductor was maintained at a constant velocity of 2.2 mph and at an ambient temperature of 43.2°C. The current was increased stepwise from 0 amps to 970 amps and the center and surface temperatures were measured as a function of time. The results shown in Fig. 3 illustrate the rather large temperature gradients that can exist in an ACSR conductor under a relatively low tension of 1000 lbs. The computer program predicted the trend in temperature quite well and it approximated a temperature which more closely mirrors the surface temperature. It underpredicts the surface temperature by about 6°C at the end of the test.

SECTION 3

HARDWARE REQUIREMENTS

The hardware requirements for executing PGEAMP are as follows:

1. An IBM-PC, IBM-PC XT or IBM-PC AT with a serial port.
2. A minimum of 384 K of RAM (user memory).
3. Two double-sided disk drives or a hard disc drive unit (recommended).
4. A monitor with an 80-column width display.
5. An Intel 8087 or 80287 math coprocessor.

SECTION 4

SOFTWARE REQUIREMENTS

The software requirements necessary to execute PGEAMP are DOS 3.0 or higher.

SECTION 5

PROGRAM OPTIONS

PGEAMP consists of four main program options: steady-state calculations; transient or real-time calculations; predictive calculations of an emergency time and predictive calculations of an emergency current. This section briefly describes the philosophy behind each of these four program options.

Steady-State Option

This option allows calculation of the conductor temperature assuming that all parameters such as current and weather conditions do not vary with time. This option does not consider that any energy is stored inside the conductor. The energy generated inside the conductor as a result of I^2R heating plus any absorbed solar heat must be equal to the sum of the energy radiated and convected to the surrounding air. In the past this type of calculation has been referred to as the temperature calculated by the House and Tuttle model.

Transient Option

This program option is similar to the steady-state model except that it considers that energy can now be stored in the conductor material. In other words, this option is one which includes the thermal inertia of the conductor mass. Therefore, a transient model will show that a conductor subjected to a step change in current will have a delayed response in its temperature which results from the thermal inertia of the conductor. As a comparison with the transient model, a steady-state option will predict an instantaneous change in conductor temperature whenever there is a change in any of the thermal conditions affecting the temperature of the conductor. This type of calculations is often referred to as a temperature resulting from a real-time ampacity model.

Time-Predictive Option

This predictive program option permits the user to predict the temperature of the conductor when it is subjected to a step change in current. The user must specify the value of the overload current and the program returns the time required for the conductor to reach an emergency limiting temperature which is also specified by the user.

The scheme used by PGEAMP for calculating an emergency time is shown graphically in Fig. 4. The theory behind this calculation stems from the desire to give the operating engineer a single value of time so that he can quickly take corrective action in the event of an emergency current overload. If this predicted time is very short, say between a few seconds or a few minutes, then the operator knows he is dealing with a heavily loaded line with practically no spare thermal capacity. If an emergency overload occurs on that particular line, then switching of current to other circuits will be necessary or the circuit may become quickly overheated. On the other hand, if the program predicts an emergency time that is closer to an hour or greater, then the line is rather lightly loaded and it has a relatively large capacity to respond to an overload in current without reaching a dangerous temperature level.

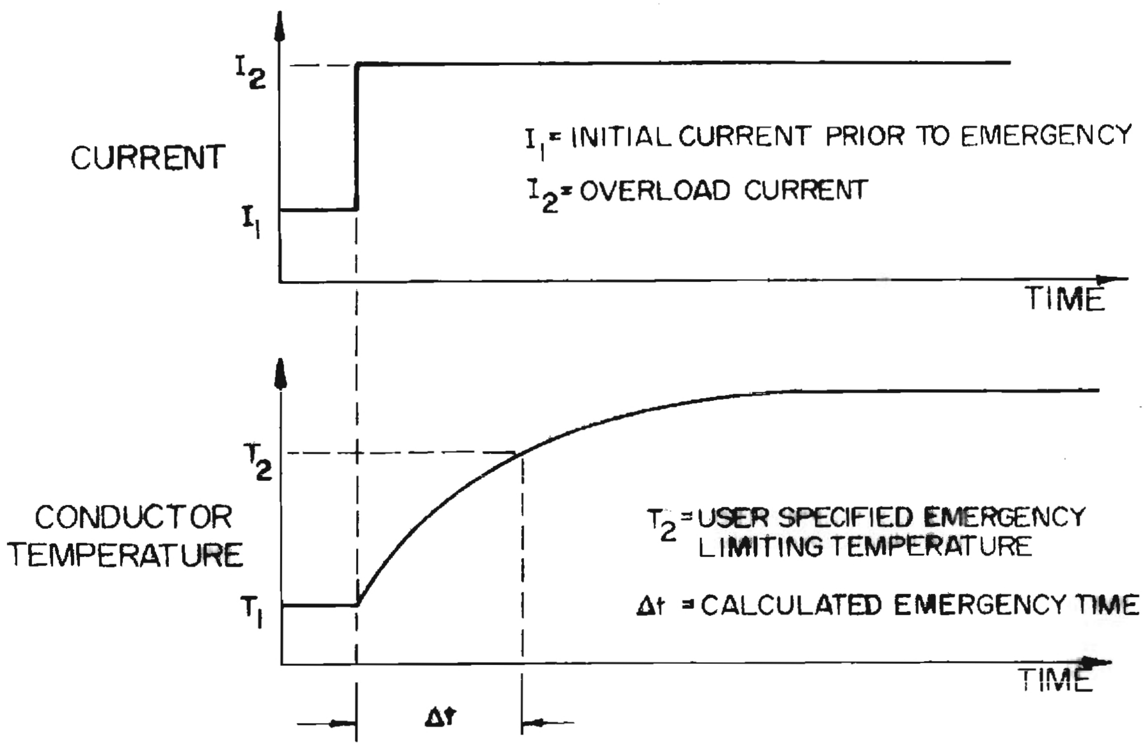

Figure 4. Scheme Used to Calculate Emergency Time for Time-Predictive Option.

Current-Predictive Option

This program option is similar to the time-predictive option except that the philosophy to calculate the spare thermal capacity of the conductor when subjected to a step change in current has been inverted. In this option the program knows the present value for the current and the present value of the weather conditions. The program is expected to determine an overload current necessary to cause the conductor temperature to increase to a known value in a given amount of time. This type of calculation is shown graphically in Fig. 5.

The reasoning behind making this type of predictive calculation is quite similar to the one used in the time-predictive calculation. In this case, however, the operator is now being provided with a limiting current instead of a limiting time. The current value may be somewhat easier to use, because operators can then see the maximum current that the particular line can accept without overheating in a predetermined allotted time. If the emergency current is only slightly over the present current being carried by the conductor, the conductor is heavily loaded with little or no excess thermal capacity in the event of an emergency. If the emergency current is far in excess of the present value, the conductor is lightly loaded and it can carry a large emergency overload.

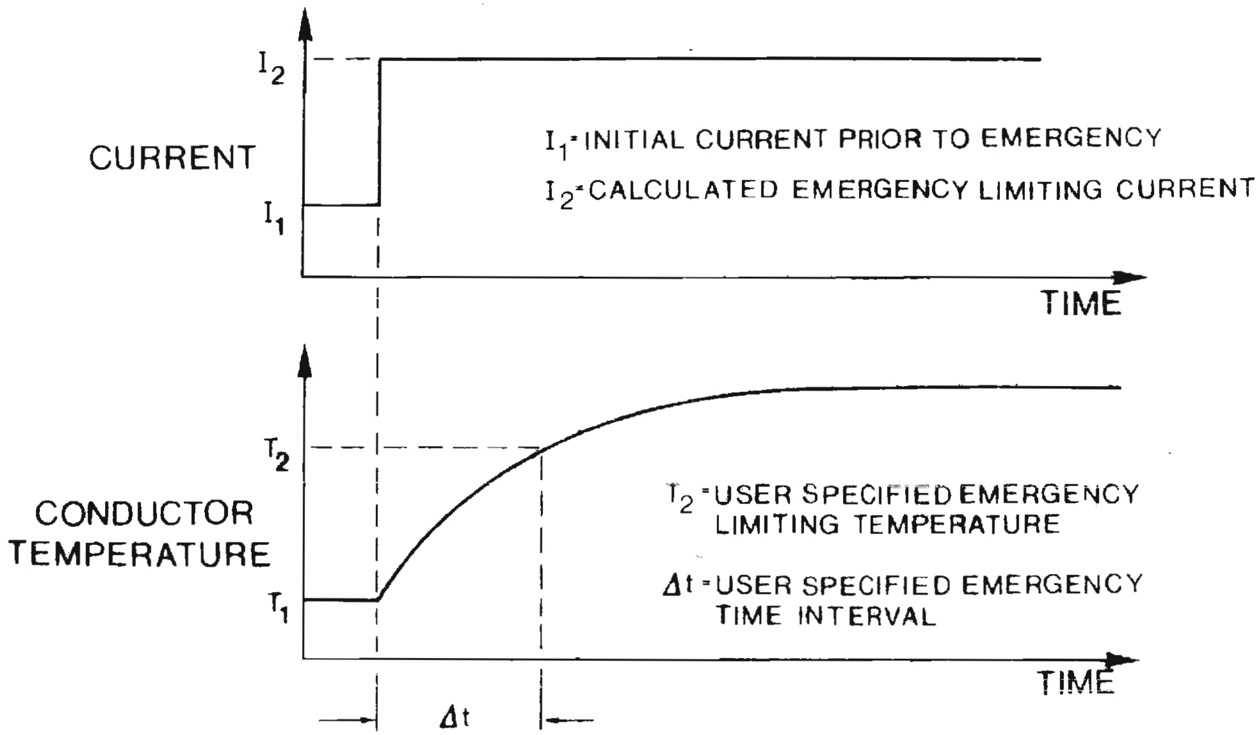

Figure 5. Scheme Used to Calculate Emergency Current for Current-Predictive Option.

SECTION 6

EXECUTING PGEAMP

PGEAMP can be executed only after the user has established both a PROTOCOL and PROPERTIES input file. Output values that are calculated by the program must be written to an ANSWER output file. Incoming weather data and conductor current can be stored in a DATA STORAGE output file. This section briefly describes both types of input and output files.

Input Files

There are two different types of input files that the user must assemble before PGEAMP can be executed. The first is called a PROTOCOL input file that is used to communicate information to the program like the baud rate and the number of data and stop bits. The second input file is a PROPERTIES file that contains all of the information relating to the conductor properties. When the PROTOCOL and PROPERTIES files are combined, they constitute the entire set of input information necessary to execute PGEAMP.

The PROTOCOL input file is assembled in the following format.

```
Line 1:  Baud Rate
Line 2:  Work Length
Line 3:  Parity
Line 4:  Parity Enable
Line 5:  Number of Stop Bits
```

The Baud rate can be either 300, 1200 or 2400 bits per second. The word length must be either 7 or 8. The parity is selected according to whether the parity enable bit which appears on Line 4 is set (Parity Enable=1) or not (Parity Enable=0). A parity value of 2 specifies even parity and a value of 1 indicates odd parity. The number of stop bits must be equal to 1 or 2.

An example of a PROTOCOL input data file for a Baud rate of 1200 bits per seconds, a word length of seven data bits, even parity and one stop bit is as follows:

```
1200
 7
 2
 1
 1
```

The PROPERTIES input file contains the following information:

```
Line 1:  ISTDY   LINE
Line 2:  ITYPE   DIAI DCOND DCORE NSCOND NSCORE RAC
Line 3:  LATD LONG TZONE BETA GAMMA ELEV
Line 4:  SUNA EMISS
```

These input variables and their meanings are defined below.

<u>Line 1:</u>

ISTDY=1	Steady-state program option used to calculate a single conductor temperature for a single value for current and a fixed set of weather conditions.

=2	Transient or real-time program option used to calculate a time varying conductor temperature for an array of currents and weather conditions which change with time.
=3	Predictive program option used to calculate a time required for the conductor temperature to increase from its present value to an emergency limiting temperature when subjected to a step change in current. This predictive program option is called the time-predictive model.
=4	Predictive program option used to calculate a current required for the conductor to increase from its present temperature to an emergency limiting temperature in a specified time when the current changes in a step-fashion. This predictive option is called the current-predictive mode.
LINE	The number corresponding to the particular line being monitored. Each line being monitored is assigned a number for reference purposes and the value for LINE ranges from 1 to 25.

Line 2:

Note:	Composite conductors, such as ACSR conductors, consist of two layers of different types of strands. The inner supporting strands are referred to as "core" strands. The outer current-carrying strands are called the "conductor" strands.
ITYPE=1	ACSR Conductor
2	AAC 1350-H19 Conductor
3	AAAC 6201-T81 Conductor
4	ACAR Conductor
5	All Copper Conductor
6	Alumoweld Conductor
7	AAAC 5005-H19 Conductor
8	SSAC Conductor
DIAI	Outer diameter of conductor in inches
DCOND	Diameter of individual conductor strands in inches
DCORE	Diameter of individual core strands in inches. This value is ignored for composite conductors with no core strands; that is conductors for which core and conductor material are identical (ITYPE=2,3,5,7).

NSCOND	Number of strands of conductor material, not including core strands.
NSCORE	Number of strands of core material.
RAC	The A.C. resistance of the composite conductor in o hms per mile at 25^{o}C.

Line 3:

LATD	Latitude of the conductor location in degrees north from the equator (See map in Fig. 6 for values).
LONG	Longitude of the conductor location in degrees east of Greenwich, England (See map in Fig. 6 for values).
TZONE=1	Eastern Time Zone
2	Central Time Zone
3	Mountain Time Zone
4	Pacific Time Zone
BETA	The conductor inclination is the angle in degrees between a line through the conductor axis and the

horizontal plane. The end of the conductor used to determine the inclination is the same one that was used to determine the conductor azimuth (GAMMA). If the end of the conductor lies below the horizon, then the inclination is negative. If the end of the conductor used to determine the conductor azimuth lies above the horizon, then the inclination (BETA) is positive. A horizontal conductor has BETA=0.

GAMMA	Conductor azimuth which is the angle in degrees measured clockwise from north to the horizontal projection of the axis of the conductor. The conductor azimuth must be between 0 and 180^o. For example, an east-west line has GAMMA=90^o. A conductor oriented from northwest to southeast has an azimuth of 135^o. The azimuth of a north-south line can be either 0^o or 180^o.
ELEV	Elevation of the conductor above sea level in feet.

<u>Line 4:</u>

SUNA	The solar absorptivity of the conductor surface. The value of SUNA must be between 0 and 1. Recommended values for copper and aluminum conductors are given in the tables below.

EMISS — The infrared emissivity of the conductor surface. The value for EMISS must be between 0 and 1. Recommended values for copper and aluminum conductors are given in the tables below.

COPPER CONDUCTORS	
Oxidization	Absorptivity
None	0.23
Light	0.5
Normal	0.7
Heavy	1.0

ALUMINUM CONDUCTORS		
Years in Service	Line Voltage <15 kV	>15 Kv
0	0.43	0.43
5-10	0.55	1.00
10-20	0.66	1.00
20-30	0.80	1.00
> 30	0.90	1.00

Recommended Values for Solar Absorptivity (SUNA) for Copper and Aluminum Conductors.

COPPER CONDUCTORS	
Oxidization	Emissivity
None	0.03
Light	0.3
Normal	0.5
Heavy	0.8

ALUMINUM CONDUCTORS		
Years in Service	Line Voltage <15 kV	>15 Kv
0	0.23	0.23
5-10	0.35	0.82
10-20	0.46	0.88
20-30	0.60	0.90
> 30	0.70	0.90

Recommended Values for Infrared Emissivity (EMISS) for Copper and Aluminum Conductors.

These four lines of input data are the only ones necessary to use PGEAMP in either the steady-state option (ISTDY=1) or the transient option (ISTDY=2).

If PGEAMP is used in either the time-predictive option (ISTDY=3) or the current-predictive option (ISTDY=4), then a fifth line of input data must be added to the PROPERTIES file. For the time-predictive option, the fifth line of data is:

Line 5: OVLD ELTEMP

where

OVLD — The ratio of overload current to pre-overload current. This value must be greater than 1.0. The program assumes that there will be a step change from the normal current to overload current. (Example: if the normal current is 500 amps and the overload current is to be 800 amps, then the value for OVLD is 1.6).

ELTEMP — The highest conductor temperature allowed during the overload period in ^{o}C. When the program is in the time-predictive mode (ISTDY=3), it calculates the time required for the conductor temperature to reach a value specified for the emergency limiting temperature when the current increases in step fashion to the overload current (See Fig. 4).

If the current-predictive program option is selected, then the fifth line of data in the PROPERTIES input file is:

Line 5: ELTIME ELTEMP

where

ELTIME The time required for the conductor to reach the emergency limiting temperature when in the current-predictive option (ISTDY=4).

ELTEMP The highest conductor temperatures allowed during the overload period in ^{o}C. When the program is in the current-predictive mode (ISTDY=4), it calculates the current required for the conductor to reach a temperature equal to the emergency limiting temperature in the time limitation given by the value for ELTIME (See Fig. 5).

Output Files

PGEAMP provides two different types of output files; the DATA STORAGE and ANSWER files. The user is given the opportunity to establish a DATA STORAGE file and if he chooses to, the program will store all of the incoming data from the remote weather station into the declared DATA STORAGE file. This option therefore provides a way of checking the data that is provided to the program from the remote station where current and weather data are collected.

The ANSWER output file contains all of the calculations provided by the program. There should be an ANSWER file for each conductor being monitored. Therefore, for example, if six lines are being monitored, there should be six separate ANSWER files.

The total number of output files varies depending upon the number of conductors that are being monitored. The number should be one more than the number of different conductors which have weather and current data sent to the program. One output file is required for the DATA STORAGE file and the remaining files correspond to each of the monitored conductors. Therefore if 18 lines are being monitored and have data sent to the computer, 19 output files must be established. Eighteen are ANSWER files for each of the 18 conductors and one is a DATA STORAGE file.

SECTION 7

OPERATION OF PGEAMP ON AN IBM-PC

The following steps illustrate the way in which PGEAMP can be executed on an IBM-PC. The user must first create both a single PROTOCOL file and a PROPERTIES input file for each conductor being monitored. These files must be established according to the guidelines outline in the previous section. Once the input files have been created, log onto the drive unit that contains PGEAMP and the input data files. Type

PGEAMP

and the computer will clear the screen and wait until any key is pressed.

Then the following prompt will appear:

```
ENTER THE NAME OF THE PROTOCOL INPUT FILE →
```

In response to this prompt, the user is expected to enter the name of the single PROTOCOL file. When the name of the PROTOCOL file is given, the following message will appear:

```
MAXIMUM NUMBER OF CONDUCTOR LOCATIONS ALLOWED IS: 25
```

as a reminder that no more than 25 different lines can be considered. After this message, the computer will provide a second prompt:

TOTAL NUMBER OF CONDUCTOR LOCATIONS SENDING DATA?

The user is expected to enter the total number of conductors which will have weather and current data provided regardless of whether the conductors are to have calculated temperatures. This number must be a positive integer less than or equal to 25. After responding to this prompt, the program will list another prompt:

NUMBER OF CONDUCTOR LOCATIONS MONITORED?

The user is expected to supply the total number of conductors that are to have their temperature calculated. This number should be equal to or less than the number provided in the previous prompt (total number of conductors sending data).

The next prompt that appears will be:

WHICH CONDUCTOR LOCATION(S) WILL BE MONITORED?

The user is expected to provide an integer number for each conductor location monitored. The number of entries provided here must equal the answer to the previous prompt. For example, suppose the temperature of three conductors are to be monitored and they are designated as conductors 3, 5 and 7. The user should then type

```
3<CR>
5<CR>
7<CR>
(no commas are permitted)
```

The next prompt that will appear is:

```
WOULD YOU LIKE TO SPECIFY A DATA STORAGE FILE (Y/N)?
```

If you select "Y", then the following prompt will appear:

```
ENTER THE NAME OF THE DATA STORAGE FILE →
```

You need only supply a single name regardless of the number of conductors being monitored because all data can be stored on a single data storage file. If you select "N" then the screen will clear and the prompt will be:

```
STATE THE PROPERTIES AND ANSWER FILES FOR CONDUCTOR LOCATION XX:
```

The program will proceed through each conductor location specified by the value of XX and ask the following two questions:

```
WHAT IS THE NAME OF THE PROPERTIES INPUT FILE?
```

and also

```
WHAT IS THE NAME OF THE ANSWER OUTPUT FILE?
```

The user is expected to supply names for both files for each conductor location that is to be monitored. Once completed, the screen will clear and the following message will appear:

```
PRESENT SERIAL CONFIGURATION PARAMETERS ARE:


BAUD        WORD          PARITY            # OF STOP
RATE        LENGTH    (0=N, 1=E, 2=0)         BITS

XXXX          X              X                 X

  PRESS <CTRL-V> TO TURN SCREEN PRINTING ON (DEFAULT)
  PRESS <CTRL-W> TO TURN SCREEN PRINTING OFF
  PRESS <CTRL-X> TO TERMINATE EXECUTION
```

When the message:

```
SETUP COMPLETED.  READY TO RECEIVE DATA
```

appears, start sending conductor current and weather data and the calculated conductor temperatures will follow as the incoming weather station data is received. Program calculations will continue uninterrupted as long as input data is available.

SECTION 8

PROGRAMMING RECOMMENDATIONS

The program internally sets the stack size equal to 64,000 bytes, so the user does not need to be concerned about adjusting the value for the stack size.

The program assumes that all lines that are being monitored are all run under the same program option. Different program options for separate conductors cannot be accommodated in a single run. Therefore, conductor number 1 cannot be run under steady-state conditions while conductor number 2 is run under the predictive or transient option.

The program execution can be terminated by pressing <CTRL-X>. The user should not use either <CTRL-C> or <CTRL-BREAK>.

The user should only use valid input and output file names. The operating system will check file names for validity, but it may not always catch inconsistencies. Input values for both PROTOCOL and PROPERTIES files must be only positive numerical values.

The program internally sets the time interval for calculations of conductor temperature and for the printing interval from the weather station output data. The program uses the time that data is received from the remote stations for these calculations. Any reasonable time interval is acceptable; however, the minimum value is one minute and a value greater than about twenty minutes will cause calculations to approach steady-state temperatures, even though the transient option is selected.

SECTION 9

EXAMPLES OF PROGRAM INPUT AND OUTPUT

This section contains examples of typical program input and output for the four major program options: steady-state, transient, time-predictive and current-predictive.

All calculations are carried out for a conductor located near San Ramon (Pacific time zone, latitude = 38^{o}, longitude=122^{o}, elevation = 600 ft) for times starting near midnight on June 11. The conductor has a surface solar absorptivity of 0.5 and an emissivity of 0.3. The conductor is oriented horizontally in a north-south direction. The type of conductor and weather conditions vary with the control option.

Steady-State Option

As a first example, consider the parameters given above and calculate the steady-state conductor temperature for a AAC (1350 Aluminum) Marigold conductor (61 strands, 0.1351 inch strand diameter, 0.0872 ohms/mile A.C. resistance at 25^{o}C). After the user assembles a PROTOCOL and PROPERTIES input file for this example and executes the program, PGEAMP will calculate the steady-state conductor temperature as long as line current, air temperature, wind direction and wind speed data are provided. Typical program output for a string of weather and current data is shown below.

The output file for this example is typical of all of the program options. The program first reiterates all of the input data which is segregated into five major groups

LOCATION AND CONTROL OPTIONS

CONDUCTOR GEOMETRY

POSITION VARIABLES

RADIATION PROPERTIES

TIME VARIABLES

All of the input information that appears in each of these five groups is self-explanatory.

Following this input information, the output shown on page two lists five calculated values including the mass and cross-sectional area of both the core and conductor strands and the skin effect calculated from the input value for AC resistance and the calculated value for the D.C. resistance.

Finally, the calculated conductor temperatures appear on page three of the output. The first column contains the Julian date which is 162 or June 11. The next column contains the minute after midnight, which for this particular problem is indexed by 20 minutes. Therefore data is being sent at 12:05 am and each subsequent set of data arrive in 20 minute intervals after 12:05 am. The next column shows the conductor number which for this example was selected to be 1. That is the value for LINE was selected to be 1. The next four columns list the data reported by the weather station in the following order: current in amps, ambient air temperature in ^{o}C, wind speed in m/s and wind direction in degrees from north. The final two columns contain the two calculated values. They are the rate at which heat is generated in the conductor due to I^2R losses in W/m and the conductor temperature in ^oC.

It is important to remember that for this program option, the calculated conductor temperature is a steady-state value. Therefore, this is the temperature of the conductor assuming the current and weather conditions shown on the same row of data are independent of time. This temperature is equivalent to the temperature calculated by the House and Tuttle method.

Computer model for dynamic ampacity calculations of overhead conductors developed by the Georgia Institute of Technology and Pacific Gas and Electric Company under contract Q01. The program will predict the Steady State, Real-time (Transient), and Predictive temperatures for eight types of conductors and twenty five different conductor locations.
Version 3.01 was completed on June 5, 1987

LOCATION AND CONTROL OPTION
****

Conductor location monitored is :		1
ISTDY	-Steady State calculations	ONE

CONDUCTOR GEOMETRY
****

ITYPE	-All aluminum 1350 conductor (AAC)		TWO
DIAI	-Outer conductor diameter	1.2160	inches
DCOND	-Conductor strand diameter	0.1351	inches
DCORE	-Core strand diameter	0.0000	inches
NSCOND	-No. of strands of conductor	61	
NSCORE	-No. of strands of core	0	
RAC	-A.C. res. of cond. @25 deg. C	0.0872	Ohms/mile

POSITION VARIABLES
****

TZONE	-Pacific time zone		FOUR
LATD	-Latitude	38.00	deg
LONG	-Longitude	122.00	deg
BETA	-Conductor axis above horizon	0.00	deg
GAMMA	-Conductor axis cw from North	0.00	deg
ELEV	-Elevation above sea level	600.00	ft

RADIATION PROPERTIES
****

SUNA	-Solar absorptivity of conductor	0.5000
EMISS	-Conductor emissivity	0.3000

TIME VARIABLES

```
***********************************************************
IMONTH  -Month of the year                      6
IDAY    -Day of the month                      11
IHOUR   -Hours from midnight                    0
IMIN    -Minutes into hour                      5
```

CALCULATED VALUES

```
***********************************************************
MCOREI  -Mass of core per unit length    0.0000 lbs/ft
MCONDI  -Mass of cond. per unit length   1.0452 lbs/ft
ARCOND  -Area of conductor               0.8744 sq. in.
ARCORE  -Area of core                    0.0000 sq. in.
SKIN    -Skin effect of conductor        1.0428
```

STEADY STATE CALCULATIONS

<-------------			MEASURED	VALUES	--------------	--><	- CALCULATED VALUES	->
JULIAN DATE	TIME min	COND. LOC.	COND. CURNT Amp	AMB. TEMP. deg C	WIND SPEED m/s	WIND DIR deg.	GEN. HEAT W/m	COND. TEMP. deg C
162	5	1	1600	40.3	9.2	0	183.97	107.4
162	25	1	167	19.0	11.7	45	1.48	19.2
162	45	1	239	18.1	10.2	135	3.02	18.6
162	65	1	362	18.7	8.3	180	7.00	21.4
162	85	1	347	19.1	8.5	180	6.44	21.6
162	105	1	315	19.1	7.8	232	5.27	20.1
162	125	1	254	22.0	7.7	230	3.46	22.6
162	145	1	192	16.9	9.4	239	1.94	17.2
162	165	1	139	18.5	9.6	236	1.02	18.7
162	185	1	93	16.3	7.6	223	0.45	16.4
162	205	1	91	16.7	1.9	222	0.43	16.9
162	225	1	69	15.1	10.0	228	0.25	15.1
162	245	1	70	15.1	10.8	230	0.26	15.1
162	265	1	69	16.8	2.9	243	0.25	16.9
162	285	1	48	14.9	3.7	213	0.12	14.9
162	305	1	64	14.9	6.6	219	0.21	15.6
162	325	1	101	16.1	1.2	153	0.54	20.3
162	345	1	142	15.1	0.8	155	1.08	22.1
162	365	1	238	15.2	3.3	62	2.99	18.6
162	385	1	290	12.7	0.6	62	4.51	22.5
162	405	1	371	15.1	2.7	57	7.33	20.8
162	425	1	394	16.4	1.5	81	8.39	24.3
162	445	1	416	19.2	0.6	26	9.83	37.3
162	465	1	449	21.9	1.2	195	11.54	39.2
162	485	1	448	22.3	7.1	245	10.95	26.7
162	505	1	762	24.6	5.7	257	32.60	34.1
162	525	1	865	25.0	6.7	248	42.29	35.9
162	545	1	968	26.3	6.1	237	53.96	40.8
162	565	1	482	26.2	7.4	239	12.92	31.7
162	585	1	497	27.1	7.5	247	13.79	32.7
162	605	1	487	27.2	8.7	241	13.23	32.5
162	625	1	479	26.9	9.9	245	12.77	31.8
162	645	1	457	26.9	9.5	249	11.62	31.7
162	665	1	414	26.2	9.4	246	9.50	30.8
162	685	1	398	24.6	12.3	244	8.70	28.5
162	705	1	354	23.3	12.3	243	6.84	27.0
162	725	1	139	20.3	9.2	238	1.04	23.8
162	745	1	567	19.0	11.7	235	17.38	24.4
162	765	1	239	18.1	10.2	229	3.06	21.8
162	785	1	362	18.7	8.3	229	7.06	23.6
162	805	1	347	19.1	8.5	229	6.49	23.9
162	825	1	315	19.1	7.8	232	5.35	23.8
162	845	1	254	22.0	7.7	230	3.52	26.4
162	865	1	192	16.9	9.4	239	1.96	20.4

Transient Option

Work the same problem as the one stated in the steady-state option, except calculate the transient conductor temperature. The input information and the calculated conductor temperature are shown in the output file below. The only change to the input file is the change from ISTDY=1 to ISTDY=2 and in this example the reference number assigned to the conductor that is being monitored is changed from 1 to 2.

The output information starting on page 3 shows the same type of output as discussed in the steady-state example except that the weather and current data have been changed and the data is first received at 12:10 am. The data is still received on a 20 minute interval like the steady-state example. In this example the calculated conductor temperature appearing in the last column is the transient temperature that exists as time passes. This calculation is distinctly different from the previous example where the conditions such as current and weather were assumed to be independent of time.

Computer model for dynamic ampacity calculations of overhead conductors developed by the Georgia Institute of **Technology. and Pacific Gas and Electric Company** under contract Q01. The program will predict the Steady State, Real-time (Transient), and Predictive temperatures for eight types of conductors and twenty five different conductor locations.
Version 3.01 was completed on June 5, 1987

LOCATION AND CONTROL OPTION

****

Conductor location monitored is :		2
ISTDY	-Transient calculations	TWO

CONDUCTOR GEOMETRY

****

ITYPE	-All aluminum 1350 conductor (AAC)		TWO
DIAI	-Outer conductor diameter	1.2160	inches
DCOND	-Conductor strand diameter	0.1351	inches
DCORE	-Core strand diameter	0.0000	inches
NSCOND	-No. of strands of conductor	61	
NSCORE	-No. of strands of core	0	
RAC	-A.C. res. of cond. @25 deg. C	0.0872	Ohms/mile

POSITION VARIABLES

****

TZONE	-Pacific time zone		FOUR
LATD	-Latitude	38.00	deg
LONG	-Longitude	122.00	deg
BETA	-Conductor axis above horizon	0.00	deg
GAMMA	-Conductor axis cw from North	0.00	deg
ELEV	-Elevation above sea level	600.00	ft

RADIATION PROPERTIES

****

SUNA	-Solar absorptivity of conductor	0.5000
EMISS	-Conductor emissivity	0.3000

TIME VARIABLES

****

```
IMONTH  -Month of the year                    6
IDAY    -Day of the month                    11
IHOUR   -Hours from midnight                  0
IMIN    -Minutes into hour                   10
```

CALCULATED VALUES

****

```
MCOREI  -Mass of core per unit length   0.0000 lbs/ft
MCONDI  -Mass of cond. per unit length  1.0452 lbs/ft
ARCOND  -Area of conductor              0.8744 sq. in.
ARCORE  -Area of core                   0.0000 sq. in.
SKIN    -Skin effect of conductor       1.0428
```

TRANSIENT CALCULATIONS

****

<------------- MEASURED	VALUES					--------------><- CALCULATED VALUES	->
JULIAN DATE	TIME min	COND. LOC.	COND. CURNT Amp	AMB. TEMP. deg C	WIND SPEED m/s	WIND DIR deg.	GEN. HEAT W/m	COND. TEMP. deg C
162	10	2	115	19.9	9.8	45	0.70	20.0
162	30	2	191	18.7	11.2	90	1.93	19.0
162	50	2	244	18.0	10.4	135	3.14	18.5
162	70	2	394	18.0	8.4	180	8.26	20.5
162	90	2	351	17.9	9.3	232	6.52	19.0
162	110	2	303	18.9	8.4	230	4.87	19.7
162	130	2	234	21.0	8.1	227	2.92	21.4
162	150	2	173	18.7	7.9	234	1.58	19.1
162	170	2	124	17.5	10.7	234	0.81	17.7
162	190	2	94	16.0	7.4	220	0.46	16.2
162	210	2	84	17.2	3.4	239	0.37	17.2
162	230	2	73	16.8	10.6	231	0.28	16.9
162	250	2	73	15.6	11.4	226	0.28	15.7
162	270	2	61	13.0	2.4	173	0.19	13.6
162	290	2	52	15.2	5.3	210	0.14	15.0
162	310	2	67	15.0	1.8	162	0.24	17.0
162	330	2	107	15.2	0.8	124	0.61	19.0
162	350	2	159	17.3	1.4	226	1.36	22.3
162	370	2	250	12.7	3.8	78	3.27	16.4
162	390	2	321	13.7	0.3	99	5.51	21.5
162	410	2	378	15.5	2.7	68	7.62	21.1
162	430	2	408	16.9	0.8	93	9.05	25.9
162	450	2	443	20.0	1.3	58	10.84	30.0
162	470	2	443	21.8	6.0	246	10.71	26.9
162	490	2	444	22.9	6.4	251	10.78	27.4
162	510	2	457	24.8	6.0	255	11.53	29.7
162	530	2	474	25.6	6.1	245	12.47	31.1
162	550	2	487	26.6	6.4	245	13.22	32.3
162	570	2	485	26.6	7.0	239	13.12	32.3
162	590	2	499	26.9	8.2	243	13.88	32.3
162	610	2	482	27.2	9.4	238	12.95	32.3
162	630	2	470	26.7	9.9	246	12.28	31.5
162	650	2	435	26.5	10.3	249	10.50	31.0
162	670	2	400	25.8	11.0	243	8.84	30.0
162	690	2	376	24.3	12.4	244	7.76	28.1
162	710	2	353	23.0	11.5	239	6.80	26.9
162	730	2	115	19.9	9.8	239	0.71	23.4
162	750	2	191	18.7	11.2	231	1.95	22.1
162	770	2	244	18.0	10.4	230	3.18	21.7
162	790	2	394	18.0	8.4	233	8.34	22.9

162	810	2	351	17.9	9.3	232	6.61	22.4
162	830	2	303	18.9	8.4	230	4.94	23.3
162	850	2	234	21.0	8.1	227	2.97	25.1
162	870	2	173	18.7	7.9	234	1.61	22.7
162	890	2	124	17.5	10.7	234	0.82	20.7
162	910	2	94	16.0	7.4	220	0.47	20.0
162	930	2	84	17.2	3.4	239	0.38	22.3
162	950	2	73	16.8	10.6	231	0.28	19.7
162	970	2	73	15.6	11.4	226	0.28	18.3
162	990	2	61	13.0	2.4	173	0.20	22.0
162	1010	2	52	15.2	5.3	210	0.14	19.6
162	1030	2	67	15.0	1.8	162	0.24	23.2
162	1050	2	107	15.2	0.8	124	0.61	22.7
162	1070	2	159	17.3	1.4	226	1.37	24.3
162	1090	2	250	12.7	3.8	78	3.27	16.3
162	1110	2	321	13.7	0.3	99	5.48	20.2
162	1130	2	378	15.5	2.7	68	7.57	19.4
162	1150	2	408	16.9	0.8	93	8.91	22.1
162	1170	2	443	20.0	1.3	58	10.62	24.6
162	1190	2	443	21.8	6.0	246	10.60	24.1
162	1210	2	444	22.9	6.4	251	10.68	24.9
162	1230	2	457	24.8	6.0	255	11.40	26.9
162	1250	2	474	25.6	6.1	245	12.32	28.0
162	1270	2	487	26.6	6.4	245	13.06	29.1
162	1290	2	485	26.6	7.0	239	12.95	29.1
162	1310	2	499	26.9	8.2	243	13.72	29.3
162	1330	2	482	27.2	9.4	238	12.80	29.3
162	1350	2	470	26.7	9.9	246	12.14	28.6
162	1370	2	435	26.5	10.3	249	10.38	28.1
162	1390	2	400	25.8	11.0	243	8.74	27.1
162	1410	2	376	24.3	12.4	244	7.67	25.4
162	1430	2	353	23.0	11.5	239	6.73	24.0
163	10	2	115	19.9	9.8	239	0.70	20.2
163	30	2	191	18.7	11.2	231	1.93	19.0
163	50	2	244	18.0	10.4	230	3.14	18.5
163	70	2	394	18.0	8.4	233	8.22	19.4
163	90	2	351	17.9	9.3	232	6.52	19.0
163	110	2	303	18.9	8.4	230	4.87	19.7
163	130	2	234	21.0	8.1	227	2.92	21.4
163	150	2	173	18.7	7.9	234	1.58	19.1
163	170	2	124	17.5	10.7	234	0.81	17.7
163	190	2	94	16.0	7.4	220	0.46	16.2

Time-Predictive Option

The third example considers the calculation of an ACSR Cardinal Conductor (54/7, 1.196 inch OD, 0.1329 inch conductor and core strand diameter, 0.0973 ohms/mile A.C. resistance at 25°C). All other input information remains the same as the previous two examples. In this case ISTDY=3 indicating the time-predictive option has been selected and the conductor being monitored is specified by the number 3. The additional input variables required for this program option are OVLD=10 and ELTEMP = 50°C (See page 2 of the output file). These two values mean that the overload current is ten times the normal current reported by the weather station and the maximum temperature that is used to signify an emergency condition is 50°C.

The output shown on page 3 lists the usual output data discussed in the previous two examples plus three new columns of information. The last three columns list the overload current in amps, the overload temperature in °C and the calculated time required for the conductor to reach the emergency limiting temperature (50°C in this example). If the overload current coupled with the existing weather conditions are not sufficient to produce a conductor temperature which exceeds the emergency limiting temperature, the program calculates an elapsed time of 121 minutes (approximately two hours) and it prints the temperature reached after two hours of overload current in the next to the last column. For example, in the row of data on page three labeled as 155 minutes past midnight, the line is lightly loaded at an overload current of 1480 amps (ten times the normal current of 148 amps). For the given weather conditions, the conductor reaches only 43.9°C after two hours of this overload current. On the other hand, the data near the beginning of the file in this example, the current increases to such a degree that the conductor becomes much closer to its limiting temperature and the calculated time decreases to as low as 0.3 minutes. This low value of emergency time suggests that the conductor is operating close to its thermal limit and a ten times increase in current would quickly overload the conductor.

If a situation is encountered where the conductor temperature exceeds the input value for the emergency limiting temperature (ELTEMP) before the step change in current occurs, the program will print a warning to check the value for ELTEMP and it will print a value of zero for the calculated overload time. The zero value for overload time simply states that the conductor requires no time to reach the emergency temperature, because it is already above its limit even before the current is increased.

Computer model for dynamic ampacity calculations of overhead conductors developed by the Georgia Institute of Technology, and Pacific Gas and Electric Company under contract Q01. The program will predict the Steady State, Real-time (Transient), and Predictive temperatures for eight types of conductors and twenty five different conductor locations.
Version 3.01 was completed on June 5, 1987

LOCATION AND CONTROL OPTION
****

```
Conductor location monitored is :                    3
ISTDY   -Temperature-Predictive calculations        THREE
```

CONDUCTOR GEOMETRY
****

```
ITYPE   -Alum. 1350 cond., steel core (ACSR)     ONE
DIAI    -Outer conductor diameter          1.1960 inches
DCOND   -Conductor strand diameter         0.1329 inches
DCORE   -Core strand diameter              0.1329 inches
NSCOND  -No. of strands of conductor      54
NSCORE  -No. of strands of core            7
RAC     -A.C. res. of cond. @25 deg. C   0.0973 Ohms/mile
```

POSITION VARIABLES
****

```
TZONE   -Pacific time zone                          FOUR
LATD    -Latitude                            38.00 deg
LONG    -Longitude                          122.00 deg
BETA    -Conductor axis above horizon          0.00 deg
GAMMA   -Conductor axis  cw from North         0.00 deg
ELEV    -Elevation above sea level          600.00 ft
```

RADIATION PROPERTIES
****

```
SUNA    -Solar absorptivity of conductor      0.5000
EMISS   -Conductor emissivity                 0.3000
```

TIME VARIABLES

****

IMONTH	-Month of the year	6
IDAY	-Day of the month	11
IHOUR	-Hours from midnight	0
IMIN	-Minutes into hour	15

CALCULATED VALUES

****

TIME-PREDICTIVE VARIABLES

****

OVLD -Current overload	10.00
ELTEMP-Emergency limiting temperature	50.0 deg. C

TIME-PREDICTIVE CALCULATIONS

****

<--------- MEASURED	VALUES					----------->	<------- CALCULATED	VALUES	- -	
JULIAN DATE	TIME min	COND. LOC.	COND. CURNT Amp	AMB. TEMP. deg C	WIND SPEED m/s	WIND DIR. deg.	COND. TEMP. deg C	OVERLD CURNT Amp	OVERLD TEMP deg C	ELAPSE TIME min
162	15	3	119	19.6	9.9	0	19.9	1190	50.0	30.[illegible]
162	35	3	206	19.1	10.8	90	19.0	2060	50.0	3.0
162	55	3	260	18.3	10.4	135	18.7	2600	50.0	0.8
162	75	3	393	18.0	8.8	180	20.8	3930	50.0	0.7
162	95	3	336	18.3	7.9	231	19.9	3360	50.0	0.4
162	115	3	296	19.2	7.7	231	20.6	2960	50.0	0.5
162	135	3	231	19.1	8.4	237	19.1	2310	50.0	0.[illegible]
162	155	3	148	19.4	8.8	233	20.4	1480	43.9	121.0
162	175	3	122	19.0	8.4	229	18.0	1220	36.0	121.0
162	195	3	88	16.6	7.2	210	15.8	880	27.4	121.0
162	215	3	81	15.2	4.9	218	15.1	810	28.0	121.0
162	235	3	66	16.0	7.6	230	17.0	660	22.8	121.0
162	255	3	61	16.8	10.2	222	16.5	610	21.8	121.0
162	275	3	57	14.8	5.1	57	13.6	570	22.1	121.0
162	295	3	58	13.9	4.5	222	14.8	580	22.1	121.0
162	315	3	79	14.4	4.4	152	16.7	790	37.2	121.0
162	335	3	113	14.9	1.3	95	18.9	1130	50.0	23.6
162	355	3	187	16.6	0.9	15	24.2	1870	50.0	1.3
162	375	3	264	15.0	1.8	88	16.9	2640	50.0	0.7
162	395	3	334	13.2	2.0	65	21.1	3340	50.0	0.4
162	415	3	384	15.0	1.8	70	22.0	3840	50.0	0.3
162	435	3	404	16.7	1.4	134	30.7	4040	50.0	0.2
162	455	3	447	19.2	0.6	89	33.3	4470	50.0	0.1
162	475	3	448	21.2	3.7	244	27.1	4480	50.0	0.1
162	495	3	435	22.5	6.3	251	28.0	4350	50.0	0.2

The temperature is out of range of resistivity equations since it is 280.9 deg c. However, calculations will continue.

The temperature is out of range of resistivity equations since it is 408.8 deg c. However, calculations will continue.

162	515	3	668	24.2	6.3	251	33.1	6680	50.0	0.0
162	535	3	478	25.5	6.1	245	32.0	4780	50.0	0.1
162	555	3	477	26.0	6.4	246	31.9	4770	50.0	0.1
162	575	3	502	26.5	7.1	243	32.7	5020	50.0	0.1
162	595	3	500	26.9	7.8	240	32.7	5000	50.0	0.1
162	615	3	494	27.1	8.9	239	32.7	4940	50.0	0.1
162	635	3	458	27.0	9.4	250	31.9	4580	50.0	0.1
162	655	3	403	26.7	9.4	252	31.3	4030	50.0	0.2
162	675	3	406	25.9	10.5	242	29.4	4060	50.0	0.2
162	695	3	361	24.5	12.0	241	27.9	3610	50.0	0.3
162	715	3	339	23.5	12.0	238	26.8	3390	50.0	0.3
162	735	3	119	21.3	10.8	237	23.1	1190	37.8	121.0
162	755	3	206	19.1	10.8	228	22.0	2060	50.0	1.7
162	775	3	260	18.3	10.4	231	22.1	2600	50.0	0.7
162	795	3	393	18.0	8.8	227	23.2	3930	50.0	0.[illegible]

162	815	3	336	18.3	7.9	231	23.7	3360	50.0	0.[illegible]
162	835	3	296	19.2	7.7	231	24.3	2960	50.0	0.4
162	855	3	231	19.1	8.4	237	22.5	2310	50.0	0.8
162	875	3	148	19.4	8.8	233	23.8	1480	47.4	121.0
162	895	3	122	19.0	8.4	229	21.5	1220	39.4	121.0
162	915	3	88	16.6	7.2	210	20.3	880	30.4	121.0
162	935	3	81	15.2	4.9	218	20.7	810	31.0	121.0
162	955	3	66	16.0	7.6	230	19.7	660	24.4	121.0
162	975	3	61	16.8	10.2	222	19.5	610	22.9	121.0
162	995	3	57	14.8	5.1	57	19.3	570	23.3	121.0
162	1015	3	58	13.9	4.5	222	18.1	580	22.8	121.0
162	1035	3	79	14.4	4.4	152	21.7	790	36.5	121.0
162	1055	3	113	14.9	1.3	95	21.4	1130	50.0	20.6
162	1075	3	187	16.6	0.9	15	25.9	1870	50.0	1.0
162	1095	3	264	15.0	1.8	88	16.7	2640	50.0	0.7
162	1115	3	334	13.2	2.0	65	19.5	3340	50.0	0.4
162	1135	3	384	15.0	1.8	70	20.0	3840	50.0	0.3
162	1155	3	404	16.7	1.4	134	24.9	4040	50.0	0.2
162	1175	3	447	19.2	0.6	89	26.9	4470	50.0	0.1
162	1195	3	448	21.2	3.7	244	24.4	4480	50.0	0.[illegible]
162	1215	3	435	22.5	6.3	251	25.4	4350	50.0	[illegible]
162	1235	3	468	24.2	6.3	251	27.7	4680	50.0	0.1
162	1255	3	478	25.5	6.1	245	28.7	4780	50.0	0.1
162	1275	3	477	26.0	6.4	246	28.9	4770	50.0	0.1
162	1295	3	502	26.5	7.1	243	29.5	5020	50.0	0.1
162	1315	3	500	26.9	7.8	240	29.7	5000	50.0	0.1
162	1335	3	494	27.1	8.9	239	29.7	4940	50.0	0.1
162	1355	3	458	27.0	9.4	250	28.9	4580	50.0	0.1
162	1375	3	403	26.7	9.4	252	28.2	4030	50.0	0.2
162	1395	3	406	25.9	10.5	242	26.6	4060	50.0	0.2
162	1415	3	361	24.5	12.0	241	25.1	3610	50.0	0.3
162	1435	3	339	23.5	12.0	238	24.0	3390	50.0	0.4
163	15	3	119	21.3	10.8	237	19.9	1190	34.5	121.0
163	35	3	206	19.1	10.8	228	19.0	2060	50.0	3.2
163	55	3	260	18.3	10.4	231	18.7	2600	50.0	0.7
163	75	3	393	18.0	8.8	227	19.5	3930	50.0	0.3
163	95	3	336	18.3	7.9	231	19.9	3360	50.0	0.4
163	115	3	296	19.2	7.7	231	20.6	2960	50.0	0.5
163	135	3	231	19.1	8.4	237	19.1	2310	50.0	0.9
163	155	3	148	19.4	8.8	233	20.4	1480	43.9	121.0
163	175	3	122	19.0	8.4	229	18.0	1220	36.0	121.0
163	195	3	88	16.6	7.2	210	15.8	880	27.4	121.0

Current-Predictive Option

This final example illustrates the current-predictive program option for the same input conditions as given in the previous example. In this case ISTDY=4 indicating the current-predictive option and the conductor number being monitored is number 4. The new input parameters which are used in this option are listed under the heading entitled Current- Predictive Variables shown on page two of the output file. They are ELTIME=30 minutes and ELTEMP=80°C. These two variables mean that the program will calculate the step change in current needed for the conductor to reach 80°C in a period of 30 minutes.

The program output is shown on page 3 for a typical series of current and weather data sent by the weather station. In this particular example, the calculated overload current appears in the third from the last column and the last two columns remind the user that this current will produce an emergency temperature of 80°C after an elapsed time of 30 minutes has transpired.

If the user inserts a set of input data such that the conductor temperature is hotter than the emergency limiting temperature before the step change in current has occurred, the program will print a reduced value in current required to reach the value of ELTEMP in the time specified by the value of ELTIME. However, if the value of ELTIME is relatively short and the conductor temperature is much greater than the value for ELTIME prior to the application of the emergency current, there is no reduced current that could possibly satisfy these conditions. In other words, the conductor cannot possibly cool down quickly enough to reach ELTEMP in the time of ELTIME.

In this event, the program will return a negative current. If the cool down condition can be met with a reduced current, the program will print a positive value for the current.

Computer model for dynamic ampacity calculations of **overhead** conductors developed by the Georgia Institute of **Technology**, and Pacific Gas and Electric Company under contract Q01. The program will predict the Steady State, Real-time (Transient), and Predictive temperatures for eight types of conductors and twenty five different conductor locations.
Version 3.01 was completed on June 5, 1987

LOCATION AND CONTROL OPTION

****

Conductor location monitored is :		4
ISTDY	-Current-Predictive calculations	FOUR

CONDUCTOR GEOMETRY

****

ITYPE	-Alum. 1350 cond., steel core (ACSR)	ONE
DIAI	-Outer conductor diameter	1.1960 inches
DCOND	-Conductor strand diameter	0.1329 inches
DCORE	-Core strand diameter	0.1329 inches
NSCOND	-No. of strands of conductor	54
NSCORE	-No. of strands of core	7
RAC	-A.C. res. of cond. @25 deg. C	0.0973 Ohms/mile

POSITION VARIABLES

****

TZONE	-Pacific time zone	FOUR
LATD	-Latitude	38.00 deg
LONG	-Longitude	122.00 deg
BETA	-Conductor axis above horizon	0.00 deg
GAMMA	-Conductor axis cw from North	0.00 deg
ELEV	-Elevation above sea level	600.00 ft

RADIATION PROPERTIES

****

SUNA	-Solar absorptivity of conductor	0.5000
EMISS	-Conductor emissivity	0.3000

TIME VARIABLES

****

IMONTH	-Month of the year	6
IDAY	-Day of the month	11
IHOUR	-Hours from midnight	0
IMIN	-Minutes into hour	20

CALCULATED VALUES

****

MCOREI	-Mass of core per unit length	0.3285 lbs/ft
MCONDI	-Mass of cond. per unit length	0.8997 lbs/ft
ARCOND	-Area of conductor	0.7491 sq. in.
ARCORE	-Area of core	0.0971 sq. in.
SKIN	-Skin effect of conductor	1.0092

CURRENT-PREDICTIVE VARIABLES

****

ELTIME	-Emergency limiting time	30.0 min
ELTEMP	-Emergency limiting temperature	80.0 deg. C

CURRENT-PREDICTIVE CALCULATIONS

<--------- MEASURED	VALUES				---------->|-------		CALCULATED VALUES		-----	
JULIAN DATE	TIME min	COND. LOC.	COND. CURNT Amp	AMB. TEMP. deg C	WIND SPEED m/s	WIND DIR. deg.	COND. TEMP. deg C	OVERLD CURNT Amp	OVERLD TEMP deg C	ELAPSED TIME min
162	20	4	137	19.3	11.0	45	19.5	2353	80.0	30.0
162	40	4	210	18.8	11.1	90	18.7	2472	80.0	30.0
162	60	4	263	18.5	9.1	135	19.5	2333	80.0	30.0
162	80	4	369	18.5	7.4	180	21.1	1897	80.0	30.0
162	100	4	325	18.6	8.4	236	20.0	2032	80.0	30.0
162	120	4	276	20.1	9.1	223	22.0	2244	80.0	30.0
162	140	4	210	18.8	9.7	240	16.9	2319	80.0	30.0
162	160	4	147	17.3	9.8	239	18.5	2383	80.0	30.0
162	180	4	100	18.0	9.5	229	17.8	2326	80.0	30.0
162	200	4	82	16.7	6.5	187	16.1	1933	80.0	30.0
162	220	4	69	15.1	4.9	216	14.9	1756	80.0	30.0
162	240	4	72	15.1	6.9	234	15.6	2293	80.0	30.0
162	260	4	64	15.9	7.2	158	16.1	1835	80.0	30.0
162	280	4	54	14.8	1.7	144	14.3	1468	80.0	30.0
162	300	4	63	18.3	4.0	231	22.6	1464	80.0	30.0
162	320	4	87	19.2	4.3	177	20.6	1652	80.0	30.0
162	340	4	123	15.5	0.8	43	20.9	1362	80.0	30.0
162	360	4	217	17.5	1.6	189	24.3	1516	80.0	30.0
162	380	4	276	15.8	2.0	71	19.5	1562	80.0	30.0
162	400	4	354	13.4	1.4	54	21.5	1508	80.0	30.0
162	420	4	391	15.4	1.9	82	22.7	1590	80.0	30.0
162	440	4	427	17.1	1.4	61	29.5	1471	80.0	30.0
162	460	4	435	19.7	0.8	114	34.1	1298	80.0	30.0
162	480	4	444	21.5	4.2	244	26.6	1314	80.0	30.0
162	500	4	646	23.0	6.2	257	32.2	1997	80.0	30.0
162	520	4	866	24.5	5.8	247	36.6	1932	80.0	30.0
162	540	4	471	25.6	6.3	242	32.6	1943	80.0	30.0
162	560	4	484	26.3	6.4	241	32.3	1928	80.0	30.0
162	580	4	507	26.8	6.9	239	33.6	1950	80.0	30.0
162	600	4	486	27.2	7.6	240	32.9	1997	80.0	30.0
162	620	4	484	27.3	9.0	242	32.6	2095	80.0	30.0
162	640	4	448	27.0	9.7	247	31.7	2155	80.0	30.0
162	660	4	405	26.5	10.0	244	30.9	2184	80.0	30.0
162	680	4	414	25.6	10.6	242	29.5	2234	80.0	30.0
162	700	4	384	24.4	11.4	241	28.0	2309	80.0	30.0
162	720	4	338	23.2	11.5	239	26.6	2335	80.0	30.0
162	740	4	137	21.0	11.1	240	22.6	2357	80.0	30.0
162	760	4	210	18.8	11.1	230	21.8	2385	80.0	30.0
162	780	4	263	18.5	9.1	231	23.4	2225	80.0	30.0
162	800	4	369	18.5	7.4	227	23.7	2086	80.0	30.0

162	820	4	325	18.6	8.4	236	[illegible]	2176	80.0	[illegible]
162	840	4	276	20.1	9.1	223	25.4	2197	80.0	30.0
162	860	4	210	18.8	9.7	240	20.0	2274	80.0	30.0
162	880	4	147	17.3	9.8	239	21.6	2339	80.0	30.0
162	900	4	100	18.0	9.5	229	21.1	2282	80.0	30.0
162	920	4	82	16.7	6.5	187	23.6	1878	80.0	30.0
162	940	4	69	15.1	4.9	216	19.0	1698	80.0	30.0
162	960	4	72	15.1	8.9	234	18.1	2252	80.0	30.0
162	980	4	64	15.9	7.2	158	23.3	1783	80.0	30.0
162	1000	4	54	14.8	1.7	144	24.3	1398	80.0	30.0
162	1020	4	63	14.3	4.0	231	18.0	1464	80.0	30.0
162	1040	4	87	15.2	4.3	177	23.7	1678	80.0	30.0
162	1280	4	484	26.3	6.4	241	29.2	1970	80.0	30.0
162	1300	4	507	26.8	6.9	239	30.2	1994	80.0	30.0
162	1320	4	486	27.2	7.6	240	29.8	2042	80.0	30.0
162	1340	4	484	27.3	9.0	242	29.6	2140	80.0	30.0
162	1360	4	448	27.0	9.7	247	28.8	2200	80.0	30.0
162	1380	4	405	26.5	10.0	244	27.9	2230	80.0	30.0
162	1400	4	414	25.6	10.6	242	26.6	2280	80.0	30.0
162	1420	4	384	24.4	11.4	241	25.1	2354	80.0	30.0
162	1440	4	338	23.2	11.5	239	23.7	2380	80.0	30.0
163	20	4	137	21.0	11.1	240	19.7	2401	80.0	30.0
163	40	4	210	18.8	11.1	230	18.7	2429	80.0	30.0
163	60	4	263	18.5	9.1	231	19.5	2272	80.0	30.0
163	80	4	369	18.5	7.4	227	19.9	2136	80.0	30.0
163	100	4	325	18.6	8.4	236	20.0	2224	80.0	30.0
163	120	4	276	20.1	9.1	223	22.0	2244	80.0	30.0
163	140	4	210	18.8	9.7	240	16.9	2319	80.0	30.0
163	160	4	147	17.3	9.8	239	18.5	2383	80.0	30.0
163	180	4	100	18.0	9.5	229	17.8	2326	80.0	30.0
163	200	4	82	16.7	6.5	187	16.1	1933	80.0	30.0